

WHAT IS CLAIMED IS:

1 1. An exposure method for transferring a predeter-  
2 mined pattern, which is formed on a mask including a  
3 shielding region and a transparent region, onto a  
4 specimen to be irradiated, by irradiating said mask  
5 with a light and by irradiating said specimen with the  
6 light having passed through the transparent region of  
7 said mask, comprising: dividing the light emitted from  
8 a light source into two lights so that the two lights  
9 immediately after having passed through different por-  
10 tions of said mask may have their phases opposed to  
11 each other by changing the individual optical paths  
12 for said two lights to reach said mask; and composing  
13 said two lights and irradiating said specimen with the  
14 composed light.

1 2. An exposure system to be used in the exposure  
2 method according to Claim 1, comprising a phase shift  
3 mechanism including: optical dividing means for divid-  
4 ing a light emitted from a light source into two  
5 halves; optical path varying means for changing the  
6 individual optical paths for the lights divided by  
7 said optical dividing means to reach said mask, to op-  
8 pose the phases of the lights, immediately after hav-

9 ing passed through the different portions of said  
10 mask, to each other; and optical composing means for  
11 composing the two lights having passed through said  
12 mask to irradiate said specimen with the composed  
13 light.

3. A mask to be used in the exposure method according to Claim 1, comprising a pair of circuit patterns arranged so that the light having passed through the transparent region of a first circuit pattern and the light having passed through the transparent region of a second circuit pattern may come close to each other on said specimen.

4. A mask including first and second patterns each having a shielding region and transparent regions, so that a desired pattern may be formed on a specimen to be irradiated, by irradiating said two kinds of patterns with two lights having a phase difference and at least a partial coherence and by composing the transmitted patterns of said lights,

8            wherein the improvement resides in that said  
9            first pattern and said second pattern are formed on  
10           either a common substrate or two separate substrates  
11           so that the light having passed through the transpar-

ent regions of said first pattern and the light having  
passed through the transparent regions of said second  
pattern may interfere with each other and be weakened.

5. An exposure system comprising: a light source for emitting a luminous flux having at least a partial coherence; luminous flux dividing means for said coherent luminous flux into two halves; an optical phase shifting member disposed in either of the optical paths for composing the luminous fluxes again from said luminous flux dividing means; an optical system for composing the luminous fluxes having passed through a first pattern and a second pattern into a single luminous flux; and an optical system for reducing and projecting said single luminous flux on a specimen to be irradiated.

13 wherein the improvement resides in that the  
14 phases of the light having passed through the first  
15 pattern and the light having passed through the second  
16 pattern are shifted as long as 180 degrees by said op-  
17 tical phase shifting member to form a composed desir-  
18 able pattern on said specimen.

1 6. An exposure method wherein the first and second  
2 patterns on said mask according to Claim 4 are ir-

3 radiated with two lights having a phase difference and  
4 at least a partial coherence so that the desired pat-  
5 tern is formed on said specimen by composing the  
6 transmitted patterns of said lights.

7. An exposure method for transferring a substantially periodic opening pattern on a mask onto a photosensitive film on a plate-shaped element to be exposed, by a size-reducing projection method over a number of periods on at least one axial direction, comprising:

7 (a) positioning the mask having said substantially  
8 periodic opening pattern and said plate-shaped element  
9 relative to each other;

(b) irradiating said positioned mask with an ultra-violet or far ultraviolet monochromatic luminous flux generally at a right angle in a manner to cover a predetermined pattern on said mask; and

(c) focusing the size-reduced image of said opening pattern on the photosensitive film on said plate-shaped element by condensing the monochromatic luminous flux having passed through said opening pattern by means of lens means.

19 wherein the opening patterns in odd and even ar-  
20 rays are set to have a difference of the optical leng-

21 th of said mask so that the lights having passed  
22 through said opening patterns in the odd and even ar-  
23 rays may have a phase difference of  $(2n + 1)\pi$  [in  
24 which n: an integer].

1 8. An exposure method according to Claim 7, wherein  
2 the difference of the optical length of said mask be-  
3 tween said opening patterns in the odd and even arrays  
4 is set by forming an additional transparent film in  
5 the opening of either of said opening patterns in the  
6 odd and even arrays.

1 9. A size-reducing projection exposure system com-  
2 prising:

- 3 (a) an ultraviolet or far ultraviolet monochromatic  
4 light source for exposure;  
5 (b) luminous flux dividing means for dividing the ex-  
6 posure luminous flux emitted from said exposure light  
7 source into main and auxiliary luminous fluxes;  
8 (c) main mask holding means for holding a main mask  
9 substrate for transmitting a portion of said main lu-  
10 minous flux from the portion corresponding to said  
11 opening pattern by irradiating a first principal plane  
12 generally at a right angle with said main luminous  
13 flux;



2 cording to Claim 9, further comprising:

(1) second phase control means for controlling the phase in the optical path opposite to the side of the optical paths of said main luminous flux and said auxiliary luminous flux, at which the phase control is accomplished by said first phase control means.

1 11. A size-reducing projection exposure system ac-  
2 cording to Claim 10, wherein the optical path between  
3 said main luminous flux and said auxiliary luminous  
4 flux is set substantially equal for the exposure ex-  
5 cept the time necessary for the phase shift by adjust-  
6 ing said first and second phase control means.

1 12. A size-reducing projection exposure system com-  
2 prising:

3 (a) an ultraviolet or far ultraviolet monochromatic  
4 light source for exposure;

(b) luminous flux dividing means for dividing the exposure luminous flux emitted from said exposure light source into main and auxiliary luminous fluxes;

(c) main mask holding means for holding a main mask substrate for transmitting a portion of said main luminous flux from the portion corresponding to said opening pattern by irradiating a first principal plane

12 generally at a right angle with said main luminous  
13 flux;  
14 (d) auxiliary mask holding means for holding an auxi-  
15 liary mask substrate for transmitting a portion of  
16 said auxiliary luminous flux from the portion cor-  
17 responding to said opening pattern, by irradiating  
18 said first principal plane generally at a right angle  
19 with said auxiliary luminous flux;  
20 (e) luminous flux composing means for composing said  
21 main luminous flux and said auxiliary luminous flux  
22 having passed to emit at least one composed luminous  
23 flux;  
24 (f) a projection optical system including a plurality  
25 of lenses for focusing said composed luminous flux on  
26 the principal plane of a wafer to be exposed, by a re-  
27 ducing projection;  
28 (g) wafer holding means for holding said wafer so  
29 that the image plane by said projection optical system  
30 may aligned with the resist film on said principal  
31 plane of said exposed wafer; and  
32 (h) first phase control means for controlling the re-  
33 lative phase difference between said main luminous  
34 flux and said auxiliary luminous flux in the optical  
35 paths of said main luminous flux and said auxiliary  
36 luminous flux.



37            wherein the individual optical paths from said  
38            exposing light source to said main mask and said  
39            auxiliary mask are generally equalized for the ex-  
40            posure except the time necessary for the phase shift,  
41            by adjusting said first phase control means.

1            13. A size-reducing projection exposure system ac-  
2            cording to Claim 12, wherein the individual optical  
3            paths from the primary plane of said wafer to said  
4            main mask and said auxiliary mask are generally equal-  
5            ized for the exposure at the time necessary for the  
6            phase shift by adjusting said first phase control  
7            means.

1            14. An exposure method for transferring a pattern on  
2            at least one mask onto a wafer by a size-reducing pro-  
3            jection exposure optical system, comprising:  
4            (a) dividing an exposure luminous flux coming from an  
5            exposing ultraviolet or far ultraviolet monochromatic  
6            light into a main luminous flux and an auxiliary lumi-  
7            nous flux;  
8            (b) irradiating the first principal plane of a main  
9            mask, which has a main opening pattern of the minimum  
10           size corresponding to the vicinity of the resolution  
11           limit of said size-reducing projection exposure opti-

(c) irradiating the first principal plane of an auxiliary mask, which has an accompanying opening pattern of the minimum size far smaller than the resolution limit of said size-reducing projection exposure optical system, with said auxiliary luminous flux generally at a right angle to emit the transmitted auxiliary luminous flux from the second principal plane of said auxiliary mask;

(d) composing the emanating main luminous flux and auxiliary luminous flux with a desired phase difference to emit a composed luminous flux; and

(e) projecting said emanated composed luminous flux on the photo resist film on the principal plane of said exposed wafer by the size-reducing projection lens system of said size-reducing projection exposure optical system so that said main luminous flux and said auxiliary luminous flux may have their corresponding portions interfere with each other to focus a clear image.

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2 said desired phase difference is substantially at  $(2n$   
3  $+ 1)\pi$  (in which  $n$ : an integer).

1 16. An exposure method for transferring a pattern on  
2 at least one mask onto a wafer by a size-reducing pro-  
3 jection exposure optical system, comprising:  
4 (a) dividing an exposure luminous flux coming from an  
5 exposing ultraviolet or far ultraviolet monochromatic  
6 light into a main luminous flux and an auxiliary lumi-  
7 nous flux;  
8 (b) irradiating the first principal plane of a main  
9 mask, which has a main opening pattern, which belongs  
10 to patterns periodic on at least one axial direction  
11 and to be transferred onto said wafer, of the minimum  
12 size corresponding to the vicinity of the resolution  
13 limit of said size-reducing projection exposure opti-  
14 cal system corresponding to an odd array, with said  
15 main luminous flux generally at a right angle to emit  
16 the transmitted main luminous flux from the second  
17 principal plane of said main mask;  
18 (c) irradiating the first principal plane of an auxi-  
19 liary mask, which has an auxiliary opening pattern,  
20 which belongs to said periodic pattern and corresponds  
21 to an even array, of the minimum size in the vicinity  
22 of the resolution limit of said size-reducing projec-

tion exposure optical system, with said auxiliary luminous flux generally at a right angle to emit the transmitted auxiliary luminous flux from the second principal plane of said auxiliary mask;

(d) composing the emanating main luminous flux and auxiliary luminous flux with a desired phase difference to emit a composed luminous flux; and

(e) projecting said emanated composed luminous flux on the photo resist film on the principal plane of said exposed wafer by the size-reducing projection lens system of said size-reducing projection exposure optical system so that said main luminous flux and said auxiliary luminous flux may interfere with each other to focus a clear image corresponding to said periodic pattern.

17. An exposure method according to Claim 16, wherein said desired phase difference is substantially at  $(2n + 1)\pi$  (in which n: an integer).

18. An exposure method according to Claim 17, wherein said desired phase difference is shifted back and forth from the value of  $(2n + 1)\pi$  (in which n: an integer) so that the pattern on the wafer corresponding to the opening patterns in the odd array and the





1 24. An exposure method according to Claim 23, wherein  
2 the patterns on said first mask and said second mask  
3 are focused on different image planes on said wafer.

1 25. An exposure method according to Claim 21, wherein  
2 the two lights for illuminating said first and second  
3 masks have mutual interference.

1 26. An exposure method according to Claim 25, wherein  
2 said first and second illuminating two lights are  
3 emitted from a single light source.

27. An exposure method according to Claim 26, wherein  
said first mask is formed thereon with:

3 (a) a main opening pattern having the minimum size in  
4 the vicinity of the resolution limit of said exposure  
5 optical system; and

(b) a shifter opening pattern having a shift layer of a size far smaller than the resolution limit of said exposure optical system and corresponding to said main opening pattern.

1 28. An exposure method according to Claim 26, wherein  
2 said first mask is formed thereon with a first main  
3 opening pattern of the minimum size in the vicinity of

4 the resolution limit of said exposure optical system,  
5 wherein said second mask is formed thereon with a  
6 second main opening pattern of the minimum size in the  
7 vicinity of the resolution limit of said exposure op-  
8 tical system, wherein said first mask is formed there-  
9 on with a first accompanying pattern corresponding to  
10 said second main opening pattern, wherein said second  
11 mask is formed thereon with a second accompanying pat-  
12 tern corresponding to said first main opening pattern,  
13 and wherein said first and second accompanying pat-  
14 terns have a size far smaller than the resolution lim-  
15 it of said exposure optical system.

1 29. An exposure method according to Claim 21, wherein  
2 said first and second masks are formed on a single  
3 quartz substrate.

30. An exposure method according to Claim 24, wherein the patterns focused on said wafer and corresponding to the opening patterns on said first and second masks are so arranged in the series focal plan that they can be separated at the inside and outside of single- or multiple-connected two-dimensional drawing.

1     31. An ~~exposure~~ method according to Claim 30, wherein



2 the pattern inside of said drawing corresponds to a  
3 memory-cell-array portion.

1 32. An exposure method according to Claim 31, wherein  
2 the pattern inside of said drawing corresponds to a  
3 number of contact or through holes on said memory-  
4 cell-array portion, and wherein the pattern outside of  
5 said drawing corresponds to a plurality of contact or  
6 through holes on a peripheral circuit.

1 33. A method of inspecting a mask having a first  
2 group of opening patterns and a second group of open-  
3 ing patterns for establishing a phase difference of  
4  $(2n + 1)\pi$  (in which  $n$ : an integer) with said first  
5 group, wherein a defective portion is detected: by ir-  
6 radiating both a mask to be inspected and a reference  
7 mask, which has a plane opening pattern identical to  
8 that of said inspected mask but which will not estab-  
9 lish the phase difference between said first group  
10 opening patterns and said second group opening pat-  
11 terns, with luminous fluxes having a mutual interfer-  
12 ence; and by composing the transmitted luminous fluxes  
13 optically.

1 34. A mask inspecting method according to Claim 33,

2 wherein the patterns of said individual masks are pro-  
3 jected in an equal or enlarged scale before or after  
4 said composing operation.

35. A mask inspecting method for simultaneously inspecting a first mask having a first group of opening patterns and a second mask having a second group of opening patterns sized not to be resolved at a predetermined exposure step, comprising:

6 (a) irradiating said first mask with a first luminous  
7 flux to emit a first emanating luminous flux;

8 (b) irradiating said second mask with a second lumi-  
9 nous flux to emit a second emanating luminous flux;

10      and

(c) projecting said first and second emanating luminous fluxes at such a magnifying or reducing ratio as to resolve said second group patterns, and composing and focusing said luminous fluxes.

1 36. A mask inspecting method according to Claim 35,  
2 wherein said first and second luminous fluxes have no  
3 mutual interference.

37. A mask inspecting method wherein the opening pat-  
terns of two masks, which should be so identical that

3 cannot be resolved at a predetermined exposure step,  
4 are composed and projected with a phase difference of  
5  $(2n + 1)\pi$  (in which n: an integer) and at such a mag-  
6 nifying or reducing ratio as to revolve themselves.

1 38. A method of exposing a pattern on a mask, in  
2 which a line-and-space-pattern having the minimum size  
3 in the vicinity of the resolution limit of a projec-  
4 tion exposure system is projected and focused on a  
5 wafer by the size-reducing projection and exposure,  
6 wherein said mask has the following patterns:

7 (a) a multiplicity of band-shaped opening patterns  
8 formed periodically in one axial direction,

9 wherein the main opening patterns adjacent to one  
10 another are adapted to establish a phase difference of  
11  $\pi$  or equal to it;

12 (b) a band-shaped accompanying opening pattern formed  
13 in the vicinity of the outside of the main openings at  
14 the end portion and extending in the longitudinal di-  
15 rection of the main openings, said opening pattern  
16 having such a width as cannot be revolved by said ex-  
17 posure optical system,

18 wherein said accompanying opening pattern extends  
19 substantially along the whole length of said main  
20 opening patterns at said end portion to establish a

